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The Lister Lecture, 1964:
Wound Sepsis—From Carbolic Acid to Hyperbaric Oxygen

SIR CHARLES ILLINGWORTH, M.D., F.R.C.S.,*
Glasgow, Scotland

ABSTRACT

The history of Lister's introduction of the antiseptic system is recalled and the circumstances surrounding the original use of carbolic acid for wound treatment, which took place in the Royal Infirmary, Glasgow, on August 12, 1865, are reviewed. The fact that wound sepsis is still prevalent is emphasized, and recent researches on bacterial inhibition under hyperbaric oxygen are described.

SOMMAIRE

L'auteur rappelle l'histoire de l'introduction de l'antisepsie par Lister et évoque les circonstances entourant le premier usage de l'acide phénique dans le traitement des plaies qui eut lieu au Royal Infirmary de Glasgow, le 12 août 1865. L'auteur souligne le fait que l'infection des plaies est encore répandue et décrit les recherches modernes sur l'inhibition bactérienne au moyen d'oxygène sous une pression supérieure à la pression atmosphérique.

THE First Annual Meeting of The Canadian Medical Association was held in 1868. Just three years earlier there had occurred an important event in medical history, the birth of modern surgery as we know it, at the hands of Joseph Lister (Fig. 1) in the Royal Infirmary, Glasgow.

The elements of the story are well known: how Lister applied the fundamental discovery of Pasteur to the problem of wound sepsis; how he argued that if the fermentation of wine is due to microbes the putrefaction of tissues might have a similar cause; that if the microbes which infect wine come in dust from the air, the microbes which contaminate wounds might do likewise; and that if wine can be kept fresh by keeping out the microbes a wound might be kept clean in the same way.

The simplicity of the argument is deceptive. Now with the hindsight of a century it looks obvious. In the context of 1865 it was a flash of genius, for in the days when all wounds putrefied, when

virulent spreading infections were the rule, the very idea that such things were not inevitable must have seemed a quite revolutionary doctrine.

Until Lister's time the practice of surgery had changed but little since biblical days; for the most part the same types of operations were carried out as had been practised in Egypt in the days of the Pharaohs, in India in the lifetime of Buddha. All through these ages surgeons who enjoyed much the same status as barbers performed few operations beyond those of necessity, such as amputating gangrenous limbs, opening abscesses, cutting for stricture or for stone, and removing superficial cancers. In 1865, although anesthesia had been introduced 20 years earlier, surgeons still feared to operate, for the smallest wound might cause death from sepsis. Moreover, in Lister's day the crowded tenements of our cities harboured dirt, squalor and malnutrition, while the still more crowded hospital wards were veritable breeding grounds for the teaming bacteria of disease which spread from one patient to the next, causing suppuration, pyemia, tetanus and the dreaded hospital gangrene, so that even the simplest operation carried a high risk of death.

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*Regius Professor of Surgery, University of Glasgow, and Surgeon to the Western Infirmary, Glasgow, Scotland.

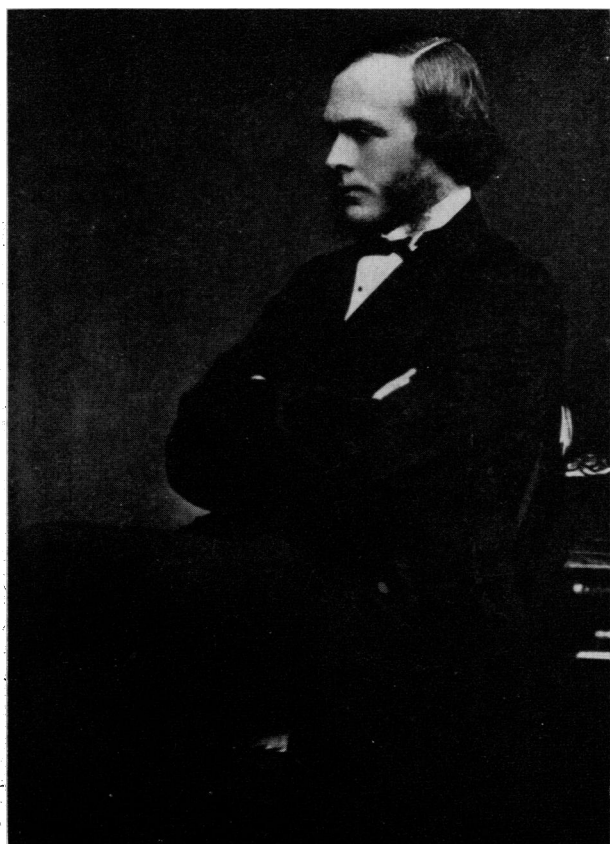


Fig. 1.—Joseph Lister aged 42. Photograph taken in Glasgow in 1869.

As a reminder of the state of surgery at that time let us examine the log book for one of Lister's wards in Glasgow Royal Infirmary, written in fine legible prose by his assistant, Dr. Robert Hamilton Ramsey (Fig. 2).

During the month of March 1864, 13 patients were admitted (Fig. 3). The average stay in hospital was about two months. There were several tuberculous joints, a leg ulcer, abscesses, burns, erysipelas. Four patients were submitted to operation—an amputation of the finger, and three tuberculous joints. Of the diseases which form the bulk of general surgical work at the present time there was hardly a single example. Patients with appendicitis, peptic ulcer, gallstones, abdominal cancer, suffered and doubtless died in their own homes. The only case of hernia was a pregnant young woman with an umbilical hernia and peritonitis, the latter probably secondary to incarceration of the hernia. No operation was performed. She died three days after admission.

Lister's first successful application of his theories of wound sepsis was carried out on August 12, 1865. Unfortunately the actual case record is not extant but there are full details of a similar case treated by orthodox methods less than a fortnight earlier, which will suffice to show the background to his discoveries (Figs. 4a and 4b).

This was a man named James Murphy, aged 40, a miner who had sustained a compound fracture

Surgical
Ward XXV

Professor Lister F.R.S.
F.R.C.S. Eng. — F.R.C.S. Ed.
Fell. Wm. Coll. Lond. — M.D. Lond.
M. Ch. Lond. — B. Ch. Lond.
Regius Professor of Surgery in the
University of Glasgow
Hon. M. R. Med. Soc. J. Edin.
F. F. Ph. S. G. — F. Med. Chir. Soc. Edin.
Surgeon
to the Glasgow Royal Infirmary
— or —
Consulting Surgeon Glasgow Royal Infirmary, Edin.
Robert Hamilton Ramsey
M.D. Assistant *G.M.*

March 25th
William Aitchison Wilson
M.D. Chm.
Assistant

July 30th 1864
Robert Hamilton Ramsey
M.D. Chm.
Assistant

Fig. 2.—Fly-leaf of case record book of one of Lister's wards in Glasgow Royal Infirmary, 1863-1865.

of the tibia and fibula. It is recorded that "Mr. Lister being unable to attend, Drs. Lyon and Morton extricated several large pieces of bone and put the leg inside wooden splints." A few days later, on August 1, 1865, the leg was put in a McIntyre splint and a poultice applied over the wound, the discharge being allowed to flow into a vessel placed beneath the splint guided by a piece of gutta percha. "A little carbolic acid was dropped into the vessel which collects the pus with the effect of preserving it quite odourless."

1874					
February	19	Miss Manderson	1	July 30	Shannon West part of Well
March	10	Joan Geers	7	April 2	Epitheloma of parotid duct
"	21	Joan Allen	8	"	Shannon West part of Well
"	"	Martha Carson	9	May 19	ulceration of coracoclav. Well
"	"	Anna Lyon	10	April 13	ulcer of large intestine Well
"	"	Eliza Kirkpatrick	11	May 24	Epithel. abscess Well
"	18	John Easton	12	Aug 26	ulcer of coracoclav. Well
"	22	Harriet Briggs	13	May 23	ulcer of large intestine Well
"	"	Miss Scott	14	March 28	Epithel. carcinoma Well
"	1	W. Little	15	March 28	ulcer of coracoclav. Well
"	26	John Armstrong	17	"	ulcer of coracoclav. Well
"	30	W. Little	18	Sept 17	ulcer of coracoclav. Well
"	"	Annie Hollenhorst	20	Aug 1	Stomach & duodenum Well
"	30	Elizabeth McKendree	21	April 30	ulcer of duodenum & jejunum Well
April	11	W. Little	22	May 14	ulcer of coracoclav. Well
"	"	Allen Jones	23	June 10	ulcer of coracoclav. Well
"	12	Flora Hunter	24	"	ulcer of coracoclav. Well
"	15	W. Little	25	"	ulcer of coracoclav. Well
April	23	John Tinsley	26	May 13	ulcer of coracoclav. Well
"	26	Anna McKinn	27	May 5	ulcer of coracoclav. Well
"	27	John Jenkins	28	July 8	ulcer of coracoclav. Well
May	9	Anna Shaw	30	May 28	ulcer of coracoclav. Well

Fig. 3.—List of patients admitted to Lister's ward 25 in the spring of 1864.

Here then the stage was set. When the next patient with a compound fracture came in, a young boy, James Greenlees, Lister was fortunately able to attend. The carbolic acid was used in this case

not as a deodorant but to sterilize the contaminated wound and keep it sterile. The success of this and succeeding cases is established history. Lister soon convinced his Glasgow colleagues of the value of his method, and in succeeding years devoted his whole efforts to convincing the world.

In Canada Lister's ideas were soon accepted, for one of his house surgeons in his Edinburgh days was a Canadian, John Stewart, who had been a student in Edinburgh. John Stewart subsequently returned to Canada, became Professor of Surgery at Dalhousie University in Halifax, Nova Scotia, and did a great deal to carry the flag of Listerism on this continent.

Since Lister's day the danger of wound sepsis has been greatly diminished, but it has been by no means eliminated, and in recent years especially the emergence of antibiotic-resistant staphylococci has drawn renewed attention to the risk, and many researches have been devoted to this subject. One of the many fascinating features about research work is that it may lead quite unexpectedly along untrodden paths to some destination far removed from the starting point. It so happens that the re-

347 James Murphy. M.
Aet 40. Miner. R.C.
Holytown.

Admitted 27th July 1865 -
A few hours before admission
while at work in the pit a large
stone fell from the roof and struck
him on the leg.

There is found to be a compound fracture of right Tibia & Fibula about their middle, there being a single wound between two & three inches in length.

Mr. Lister being unable to attend
Drs Lyon & Morton. extracted several
large pieces of bone, and put up
the leg in side wooden splints.

1st Aug^t
Leg put up on a M^cIntyre
splint, and a poultice applied

over the wound, the discharge being allowed to flow, as it forms, into a vessel placed beneath the splint, guided by a piece of inter-percha cloth.

7th

The discharge is very considerable in amount, and is pressed gently out night & morning when the poultice is changed. A little Carbolic Acid is at every dressing dropped into the vessel which collects the pus, with the effect of preserving it quite odourless.

Hab in dies ein Rubri Ziv
11.^{er}

Herb in der Gft von Ball, Fritz
Contra von Ruber
(348)

Fig. 4a

Fig. 4b

Figs. 4a and 4b.—Records of compound fracture treated in Glasgow Royal Infirmary two weeks before Lister's first successful case.

searches on hyperbaric oxygen which have been carried out in my department, although originally designed for quite different purposes, have thrown some new light on the problems of wound sepsis.

We were interested in the simple clinical problem of how to maintain the vitality of a limb after occlusion, by injury or disease, of the main artery, and this led us to try the effect of hyperbaric oxygen. Here, of course, the scientific basis has long been known, but its application to clinical problems had not been explored until first Boerema in Amsterdam and shortly afterwards my group in Glasgow began to study it.

The first question to be asked was whether, when the main blood vessel to a part was damaged or diseased, any benefit could be gained by the small excess of oxygen which could be forced in simple physical solution into the plasma under hyperbaric conditions. It was known that at two atmospheres the amount of oxygen carried in the blood could be raised from rather less than 20 volumes per cent to nearly 24 volumes, and that at three atmospheres it could be raised to 26 volumes.

It was necessary to devise an experimental situation in which ligation of a blood vessel could be relied upon consistently to give measurable effects and in which those effects might be modified by the relatively small increase in oxygen which could be obtained. Professor George Smith, on the basis of his previous experience, suggested that experimental ligation of the circumflex branch of the left coronary artery in the dog might give the answer. And so it proved. These experiments and Smith's later observations of a similar sort on obstruction of the carotid and vertebral arteries made it clear that under borderline conditions of vascularity the added oxygen under hyperbaric conditions might just tip the balance.

Since then our researches on hyperbaric oxygen have covered many different fields (Fig. 5). Some of them were related to the clinical interests of physicians, such as myocardial infarction and coronary thrombosis; some to pediatrics, for example, hyaline membrane disease and asphyxia of the newborn; some to toxicology, for example, coal-gas poisoning and barbiturate poisoning; some to heart surgery and brain surgery; some to biochemistry and some to pure bacteriology.

In the case of myocardial infarction the frequency of the disease, the uniform character of its manifestations and the accuracy of monitoring equipment have made it possible to embark on a properly controlled scientific trial which is still in progress. In neonatal asphyxias, while our first efforts on patients with hyaline membrane disease were ineffective they led my pediatric colleagues to explore the more successful field of pallid asphyxia. In coal-gas poisoning, while the theoretical basis had long been known, the practical application settled many matters which had long been in dispute. In the

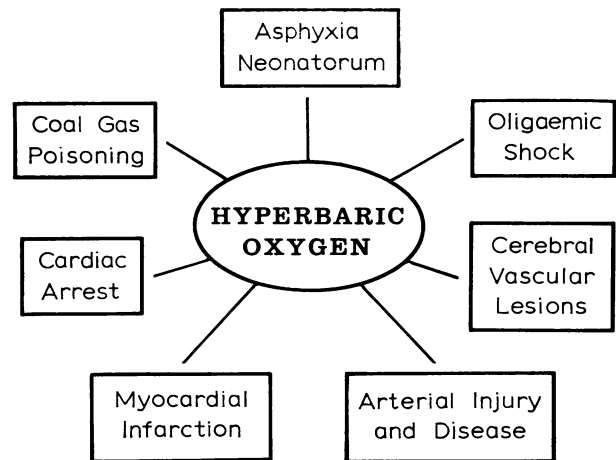


Fig. 5.—Some fields of research on hyperbaric oxygen.

field of heart surgery Iain Ledingham and Nelson Norman began their work on experimental cardiac arrest and this led in time to some fascinating observations on the part played by disturbances of acid-base balance.

Then it was thought that hyperbaric oxygen might be of value in cases of carotid artery disease. This led Jacobson, with McDowall and Murray Harper, to study the physiology of the cerebral circulation using the krypton clearance technique which Harper had perfected and to embark on an exciting voyage of discovery through all these cross currents of carbon dioxide tension, blood pressure, anesthetic toxicity and oxygen level which in the result determine the cerebral blood flow.

I mention all these matters because they show how a piece of research starting with a fairly simple surgical problem is carried step by step from one exciting field to another.

Another fertile research field based on the clinical use of hyperbaric oxygen is the problem of irreversible shock. It has been shown that in dogs a standardized degree of shock can be inflicted by withdrawing blood to the extent of reducing the systolic pressure to 40 mm. Hg and maintaining this level for an hour or two hours or more. There is evidence to suggest that if this is done while the dog is exposed to hyperbaric oxygen the degree of shock is reduced or, in other words, a much greater amount of blood must be withdrawn in order to bring about the same degree of shock. This then is not only an indication of a potentially useful treatment for shock but also a new pathway for investigation into the nature of this form of shock, into the relative importance of capillary anoxia, of splanchnic vasomotor paralysis, of metabolic acidosis, of bacterial toxemia and other such factors.

I have mentioned that an excess of oxygen might be toxic to brain cells, and indeed oxygen poisoning is a recognized risk when the gas is applied in high concentration for prolonged periods, as is well known from experiments on deep diving. It has also

been demonstrated that in slices of liver tissue exposed to pure oxygen at two atmospheres the metabolic activities may be reduced by some 40%.

Until a few months ago this poisonous quality of high oxygen concentration had been regarded as a nuisance and a hazard. It now turns out that in one respect it might prove to be advantageous.

It is well known that surgical incisions made in ischemic tissues are slow to heal and in such cases they often become infected. Amputation wounds are particularly prone to infection from this cause, especially when the amputation is done for arterial degenerative disease.

It seemed to me that hyperbaric oxygen might be of value in improving the state of nutrition of the anoxic flaps and I suggested to my associate Ross that the possibility might be investigated experimentally. He consulted his bacteriological colleagues MacAllister and Stark and they agreed to collaborate. However, as a first step they decided to study what effect hyperbaric oxygen would have on the bacteria themselves. Agar plates were inoculated with staphylococci, *Pseudomonas pyocyanea*

and other organisms, the plates were exposed to pure oxygen at two atmospheres and the results observed. The results were dramatic. These bacteria were completely inhibited and others such as *E. coli* were inhibited to a lesser extent. In their susceptibility to oxygen poisoning they behaved like cells of the brain or the liver but even more emphatically.

Thus we have a situation in which this new agent, hyperbaric oxygen, may have a double effect on a contaminated wound. It will bring more oxygen to the ischemic tissue and thus improve its nutrition and it may have a direct effect on the infecting bacteria.

We do not know that it will be effective *in vivo*, and it can hardly be expected to be so dramatic in its effects on a wound as the direct application of carbolic acid in the boy James Greenlees in 1865. But at any rate it leaves us with the salutary reflection that nearly a hundred years after Lister's first case there is still room for original research and experimentation on the subject of putrefaction in wounds.

CANADIAN JOURNAL OF SURGERY

The October 1964 issue of the *Canadian Journal of Surgery* contains the following original articles, case reports, surgical technique and experimental surgery:

Original Articles: The problem of stones in the common bile duct with particular reference to retained stones—L. G. Hampson and E. A. Petrie. Cholecystectomy with routine sphincteroplasty—J.-P. Drouin. Papillary adenomas of the colon and rectum; clinical and pathological behaviour: a plea for more conservative treatment—J. J. Derjanecz and C. W. Clark. Malignant polyps of the colon—R. E. Cram and A. F. Bond. Diagnosis and management of stomal ulcer—G. F. Bondar, W. W. Yakimets, H. T. G. Williams and W. C. MacKenzie. Elective use of two incisions in medial meniscectomy: results of 50 procedures compared with 50 single-incision meniscectomies—G. M. Novotny and A. C. Derby. Treatment of iliofemoral vein thrombosis (phlegmasia dolens) by thrombectomy—W. Sapirstein, W. R. F. Harvey and S. R. J. Ross. The surgical significance of radiation injuries to bowel—E. E. Sterns, J. A. Palmer and F. G. Kergin.

Review Article: Cancer of the bladder: biochemical factors in its etiology—W. K. Kerr, M. Barkin and Z. Menczyk.

Case Reports: Congenital solitary kidney with crossed ectopia—A. H. Irvine and H. F. Yaman. Aortic arch anomaly with aortic diverticulum causing esophageal obstruction in the adult—K. C. Grant, R. E. Wise and D. P. Boyd. Esophageal duplication presenting as a "goitre" in a 64-year-old woman—I. H. Koven and M. I. Steinhardt.

Surgical Technique: The fusion of interphalangeal joints—D. C. Robertson.

Experimental Surgery: Hemodilution during extracorporeal circulation: a preliminary report of its effects on hemolysis—J. C. Coles, J. Buttiglierio and J. Aust. Etude expérimentale de l'hypothermie profonde à l'aide de l'alcool intraveineux et de l'adrénaline—E. Bertho. Histochemical studies of the fate of autologous digital flexor tendon grafts in the chicken—J. R. Birch and W. K. Lindsay. Experimental anastomosis of the left internal mammary artery to the divided circumflex coronary artery using the NRC-Vogelfanger stapling device—S. E. Carroll.

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